



Patent Application  
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breath and spirit of the present invention as disclosed  
herein.

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What is claimed is:

- 1 1. A method for controlling the transmission of data  
2 packets through a network by controlling a Transmission  
3 Control Protocol (TCP) rate in a network device having a  
4 shared buffer with shared buffer space, the method  
5 comprising:  
6 organizing a forward data buffer into one or more  
7 queues that store at least one forward data  
8 packet;  
9 calculating the network device's advertised window  
10 size by implementing an integral control  
11 algorithm that uses information pertaining to  
12 the one or more queues;  
13 providing the network device's advertised window  
14 size to a TCP source; and  
15 calculating a dynamic buffer threshold based, at  
16 least in part, upon the sum of the queue sizes  
17 and the shared buffer space.  
18
- 1 2. The method of claim 1 wherein the step of organizing  
2 a forward data buffer further comprises:  
3 organizing the forward data buffer into one or more  
4 queues with one queue per service class.
- 1 3. The method of claim 1 wherein the at least one  
2 forward data packet is stored according to its service  
3 class.

1 4. The method of claim 1 wherein the step of  
2 calculating a network device's advertised window size  
3 further comprises:  
4 initializing a timer to a predetermined time  
5 interval  $\Delta t$ , and an iteration counter to a  
6 predetermined initial value  $n$ ;  
7 sampling a current queue size  $q_i(n)$  during the  
8 predetermined time interval  $\Delta t$ ;  
9 calculating a current error signal  $e_i(n)$  based, at  
10 least in part, upon the current queue size  
11  $q_i(n)$ ;  
12 calculating the network device's advertised window  
13 size  $W_i(n)$ , based, at least in part, upon the  
14 current error signal  $e_i(n)$  according to the  
15 equation:  $W_i(n) = [W_i(n-1) + \alpha e_i(n)]_{W_{\min}}^{W_{\max}}$ , where  $\alpha$ ,  $W_{\max}$ ,  
16 and  $W_{\min}$ , are predetermined parameters;  
17 resetting the timer, upon expiration of the  
18 predetermined interval  $\Delta t$ ; and  
19 iterating the iteration counter, upon expiration of  
20 the predetermined time interval  $\Delta t$ .

1 5. The method of claim 4 wherein the steps of  
2 calculating a current error signal  $e_i(n)$  and calculating

3 the network device's advertised window size further  
4 comprise:  
5 filtering the current error signal  $e_i(n)$  according to  
6 the relation:  $\hat{e}_i(n) = (1 - \beta)\hat{e}_i(n-1) + \beta e_i(n)$ , where  $\beta$   
7 is a predetermined parameter; and  
8 calculating the network device's advertised window  
9 size  $W_i(n)$ , based, at least in part, upon the  
10 filtered current error signal  $\hat{e}_i(n)$  according to  
11 the equation:  $W_i(n) = [W_i(n-1) + \alpha \hat{e}_i(n)]_{W_{\min}}^{W_{\max}}$ , where  $\alpha$ ,  
12  $W_{\max}$ , and  $W_{\min}$ , are predetermined parameters.

1 6. The method of claim 1 wherein the step of providing  
2 the network device's advertised window size to a TCP  
3 source further comprises:  
4 carrying information relating to the network  
5 device's advertised window size by returning  
6 TCP acknowledgements in a receiver's advertised  
7 window field.

1 7. The method of claim 1 wherein the step of providing  
2 the network device's advertised window size to a TCP  
3 source further comprises:  
4 updating a TCP receiver's advertised window size.

1 8. The method of claim 7 wherein the step of updating a  
2 TCP receiver's advertised window size further comprises:  
3 identifying whether a packet is an ACK packet, and,  
4 if not, putting the non-ACK packet in a reverse  
5 data buffer;  
6 determining a service class for the identified ACK  
7 packet;

8 reading the TCP receiver's advertised window size  
9 ( $RW_{rec}$ ) and a checksum ( $RCHKSUM$ ) from the  
10 identified ACK packet;  
11 determining whether the TCP receiver's advertised  
12 window size  $RW_{rec}$ , is less than or equal to the  
13 calculated network device's advertised window  
14 size  $W_i(n)$  and, if not setting a advertised  
15 window field in the identified ACK packet equal  
16 to the network device's advertised window size  
17  $W_i(n)$  and updating the checksum field for the  
18 identified ACK packet.

1 9. The method of claim 1 wherein the step of  
2 calculating a dynamic buffer threshold further comprises:  
3 initializing a timer to a predetermined time  
4 interval  $\Delta s$  and an iteration counter to a  
5 predetermined initial value  $n$ ;  
6 setting an initial dynamic buffer threshold  $T(0)$   
7 equal to a parameter  $\gamma$  multiplied by a buffer  
8 size  $B$  and divided by a number of service  
9 classes  $K$ ;  
10 sampling a current queue size  $q_i(n)$  during the  
11 predetermined time interval  $\Delta s$ ;  
12 calculating a sum of the sampled current queue size  
13 according to the equation:  $Q(n) = \sum_{i=1}^K q_i(n)$ ;  
14 determining whether the sum of the sampled current  
15 queue size is less than the product of the  
16 parameter and the buffer size  $\gamma B$ ;  
17 if so, updating the dynamic buffer threshold

18                   according to  $\min\{T(n-1)+\Delta T, \gamma B\}$ , where  $\Delta T$  is  
19                   a step size that controls the rate at  
20                   which the dynamic buffer threshold  
21                   changes;  
22           if not, updating the dynamic buffer threshold  
23                   according to  $\max\{T(n-1)-\Delta T, T_{\min}\}$ , where  $T_{\min}$   
24                   is a predetermined minimum size for the  
25                   dynamic buffer threshold;  
26           resetting the timer, upon expiration of the  
27           predetermined interval  $\Delta s$ ; and  
28           iterating the iteration counter, upon expiration of  
29           the predetermined time interval  $\Delta s$ .

1    10. The method of claim 9 wherein the step of  
2    calculating a sum of the sampled current queue size  
3    further comprises:  
4           filtering the sum of the sampled current queue size  
5                    $Q(n)$  according to the relation:  
6                    $\hat{Q}(n) = (1-\phi)\hat{Q}(n-1) + \phi Q(n)$ , wherein  $\phi$  is a  
7                   predetermined parameter.

1    11. An apparatus for controlling the transmission of  
2    data packets through a network by controlling a  
3    Transmission Control Protocol (TCP) rate in a network  
4    device having a shared buffer with shared buffer space,  
5    the apparatus comprising:  
6           a forward data buffer, organized into one or more  
7                   queues that store at least one forward data  
8                   packet;  
9           a network device's advertised window size  
10           calculation module that calculates a network

11 device's advertised window size by implementing  
12 an integral control algorithm that uses  
13 information pertaining to the one or more  
14 queues;  
15 a feed back module that provides the network  
16 device's advertised window size to a TCP  
17 source; and  
18 a dynamic buffer threshold module that calculates a  
19 dynamic buffer threshold based, at least in  
20 part, upon the sum of the queue sizes and the  
21 shared buffer space.

1 12. The apparatus of claim 11 wherein the network  
2 device's advertised window size calculation module  
3 further comprises:  
4 a timer, initially set to a predetermined time  
5 interval  $\Delta t$ , and an iteration counter initially  
6 set to a predetermined initial value  $n$ ;  
7 a current queue size sampler that samples a current  
8 queue size  $q_i(n)$  during the predetermined time  
9 interval  $\Delta t$ ;  
10 a current error signal calculation module that  
11 calculates a current error signal  $e_i(n)$  based,  
12 at least in part, upon the current queue size  
13  $q_i(n)$ ;  
14 a window size calculation module that calculates the  
15 network device's advertised window size  $W_i(n)$ ,  
16 based, at least in part, upon the current error  
17 signal  $e_i(n)$  according to the equation:  
18 
$$W_i(n) = [W_i(n-1) + \alpha e_i(n)]_{W_{\min}}^{W_{\max}}, \text{ where } \alpha, W_{\max}, \text{ and } W_{\min},$$

19 are predetermined parameters.

1 13. The apparatus of claim 12 wherein the current error  
2 signal calculation module further comprises:

3 a filter module that filters the current error  
4 signal  $e_i(n)$  according to the relation:

5  $\hat{e}_i(n) = (1 - \beta)\hat{e}_i(n-1) + \beta e_i(n)$ , where  $\beta$  is a  
6 predetermined parameter; and

7 wherein the window size calculation module  
8 calculates the network device's advertised  
9 window size  $W_i(n)$ , based, at least in part, upon  
10 the filtered current error signal  $\hat{e}_i(n)$   
11 according to the equation:

12  $W_i(n) = [W_i(n-1) + \alpha \hat{e}_i(n)]_{W_{\min}}^{W_{\max}}$ , where  $\alpha$ ,  $W_{\max}$ , and  $W_{\min}$ ,  
13 are predetermined parameters.

1 14. The apparatus of claim 11 wherein the feed back  
2 module further comprises:

3 an advertised window size updating module that  
4 updates a TCP receiver's advertised window  
5 size.

1 15. The apparatus of claim 14 wherein the advertised  
2 window size updating module further comprises:

3 an ACK packet identification module that identifies  
4 whether a packet is an ACK packet, and, if not,  
5 puts the non-ACK packet in a reverse data  
6 buffer;

7 an ACK packet classifier that determines a service  
8 class for the identified ACK packet;

9 an advertised window size reader that reads a TCP



10 receiver's advertised window size ( $RW_{rec}$ ) and a  
11 checksum ( $RCHKSUM$ ) from the identified ACK  
12 packet;  
13 a window size comparison module that determines  
14 whether the TCP receiver's advertised window  
15 size  $RW_{REC}$ , is less than or equal to the  
16 calculated network device's advertised window  
17 size  $W_i(n)$  and, if not sets an advertised window  
18 field in the identified ACK packet equal to the  
19 calculated network device's advertised window  
20 size  $W_i(n)$  and updates the checksum field for  
21 the identified ACK packet.

1 16. The apparatus of claim 11 wherein the dynamic buffer  
2 threshold module further comprises:  
3 a timer initially set to a predetermined time  
4 interval  $\Delta s$  and an iteration counter initially  
5 set to a predetermined initial value  $n$ ;  
6 a current queue size sampler that samples a current  
7 queue size  $q_i(n)$  during the predetermined time  
8 interval  $\Delta s$ ;  
9 a current queue size calculation module that  
10 calculates a sum of the sampled current queue  
11 size according to the equation:  $Q(n) = \sum_{i=1}^K q_i(n)$ ,  
12 where  $K$  is a number of service classes;  
13 a dynamic buffer threshold determiner that  
14 determines whether the sum of the sampled  
15 current queue size is less than the product of  
16 a parameter  $\gamma$  and a buffer size  $B$ ;  
17 and an updating module that updates the dynamic

18 buffer threshold if the sum of the sampled  
19 current queue size is less than the product of  
20 the parameter  $\gamma$  and the buffer size  $B$ ,  
21 according to  $\min\{T(n-1)+\Delta T, \gamma B\}$ , where  $\Delta T$  is a  
22 step size that controls the rate at which the  
23 dynamic buffer threshold changes and if the sum  
24 of the sampled current queue size is not less  
25 than the product of the parameter  $\gamma$  and a  
26 buffer size  $B$ , updates the dynamic buffer  
27 threshold according to  $\max\{T(n-1)-\Delta T, T_{\min}\}$ , where  
28  $T_{\min}$  is a predetermined minimum size for the  
29 dynamic buffer threshold.

1 17. The apparatus of claim 16 wherein the current queue  
2 size calculation module further comprises:

3 a filter that filters the sum of the sampled current  
4 queue size  $Q(n)$  according to the relation:

5  $\hat{Q}(n) = (1-\phi)\hat{Q}(n-1) + \phi Q(n)$ , wherein  $\phi$  is a  
6 predetermined parameter.

1 18. An article of manufacture for controlling the  
2 transmission of data packets through a network by  
3 controlling a Transmission Control Protocol (TCP) rate in  
4 a network device having a shared buffer with shared  
5 buffer space, the article of manufacture comprising:

6 at least one processor readable carrier; and  
7 instructions carried on the at least one carrier;  
8 wherein the instructions are configured to be  
9 readable from the at least one carrier by at least one  
10 processor and thereby cause the at least one processor to  
11 operate so as to:

12           organize a forward data buffer into one or more  
13           queues that store at least one forward data  
14           packet;  
15           calculate a network device's advertised window size  
16           by implementing an integral control algorithm  
17           that uses information pertaining to the one or  
18           more queues;  
19           provide the network device's advertised window size  
20           to a TCP source; and  
21           calculate a dynamic buffer threshold based, at least  
22           in part, upon the sum of the queue sizes and  
23           the shared buffer space.

1           19. The article of manufacture of claim 18 wherein the  
2           instructions are configured to be readable from the at  
3           least one carrier by at least one processor and thereby  
4           cause the at least one processor to operate so as to:  
5           organize the forward data buffer into one or more  
6           queues with one queue per service class.

1           20. The article of manufacture of claim 18 wherein the  
2           instructions are configured to be readable from the at  
3           least one carrier by at least one processor and thereby  
4           cause the at least one processor to operate so as to:  
5           store the at least one forward data packet according  
6           to its service class.

1           21. The article of manufacture of claim 18 wherein the  
2           instructions are configured to be readable from the at  
3           least one carrier by at least one processor and thereby  
4           cause the at least one processor to operate so as to:  
5           initialize a timer to a predetermined time interval

6            $\Delta t$ , and an iteration counter to a predetermined  
7           initial value  $n$ ;  
8       sample a current queue size  $q_i(n)$  during the  
9           predetermined time interval  $\Delta t$ ;  
10       calculate a current error signal  $e_i(n)$  based, at  
11       least in part, upon the current queue size  
12        $q_i(n)$ ;  
13       calculate the network device's advertised window  
14       size  $W_i(n)$ , based, at least in part, upon the  
15       current error signal  $e_i(n)$  according to the  
16       equation:  $W_i(n) = [W_i(n-1) + \alpha e_i(n)]_{W_{\min}}^{W_{\max}}$ , where  $\alpha$ ,  $W_{\max}$ ,  
17       and  $W_{\min}$ , are predetermined parameters;  
18       reset the timer, upon expiration of the  
19       predetermined interval  $\Delta t$ ; and  
20       iterate the iteration counter, upon expiration of  
21       the predetermined time interval  $\Delta t$ .

1       22.       The article of manufacture of claim 21 wherein  
2       the instructions are configured to be readable from the  
3       at least one carrier by at least one processor and  
4       thereby cause the at least one processor to operate so as  
5       to:

6           filter the current error signal  $e_i(n)$  according to  
7           the relation:  $\hat{e}_i(n) = (1 - \beta)\hat{e}_i(n-1) + \beta e_i(n)$ , where  $\beta$   
8           is a predetermined parameter; and  
9           calculate the network device's advertised window  
10          size  $W_i(n)$ , based, at least in part, upon the  
11          filtered current error signal  $\hat{e}_i(n)$  according to

12                   the equation:  $W_i(n) = [W_i(n-1) + \alpha \hat{e}_i(n)]_{W_{\min}}^{W_{\max}}$ , where  $\alpha$ ,  
13                    $W_{\max}$ , and  $W_{\min}$ , are predetermined parameters.

1       23. The article of manufacture of claim 18 wherein the  
2       instructions are configured to be readable from the at  
3       least one carrier by at least one processor and thereby  
4       cause the at least one processor to operate so as to:  
5               carry information relating to the network device's  
6               advertised window size by returning TCP  
7               acknowledgements in a receiver's advertised  
8               window field.

1       24. The article of manufacture of claim 18 wherein the  
2       instructions are configured to be readable from the at  
3       least one carrier by at least one processor and thereby  
4       cause the at least one processor to operate so as to:  
5               update a TCP receiver's advertised window size.

1       25. The article of manufacture of claim 24 wherein the  
2       instructions are configured to be readable from the at  
3       least one carrier by at least one processor and thereby  
4       cause the at least one processor to operate so as to:  
5               identify whether a packet is an ACK packet, and, if  
6               not, put the non-ACK packet in a reverse data  
7               buffer;  
8               determine a service class for the identified ACK  
9               packet;  
10              read a TCP receiver's advertised window size ( $RW_{rec}$ )  
11              and a checksum ( $RCHKSUM$ ) from the identified  
12              ACK packet;  
13              determine whether the TCP receiver's advertised

14 window size  $RW_{REC}$ , is less than or equal to the  
15 calculated network device's advertised window  
16 size  $W_i(n)$  and, if not setting an advertised  
17 window field in the identified ACK packet equal  
18 to the calculated network device's advertised  
19 window size  $W_i(n)$  and updating the checksum  
20 field for the identified ACK packet.

1 26. The article of manufacture of claim 18 wherein the  
2 instructions are configured to be readable from the at  
3 least one carrier by at least one processor and thereby  
4 cause the at least one processor to operate so as to:  
5 initialize a timer to a predetermined time interval  
6  $\Delta s$  and an iteration counter to a predetermined  
7 initial value  $n$ ;  
8 set an initial dynamic buffer threshold  $T(0)$  equal to  
9 a parameter  $\gamma$  multiplied by a buffer size  $B$   
10 and divided by a number of service classes  $K$ ;  
11 sample a current queue size  $q_i(n)$  during the  
12 predetermined time interval  $\Delta s$ ;  
13 calculate a sum of the sampled current queue size  
14 according to the equation:  $Q(n) = \sum_{i=1}^K q_i(n)$ ;  
15 determine whether the sum of the sampled current  
16 queue size is less than the product of the  
17 parameter and the buffer size  $\gamma B$ ;  
18 if so, updating the dynamic buffer threshold  
19 according to  $\min\{T(n-1) + \Delta T, \gamma B\}$ , where  $\Delta T$  is  
20 a step size that controls the rate at  
21 which the dynamic buffer threshold  
22 changes;

23           if not, updating the dynamic buffer threshold  
24               according to  $\max\{T(n-1)-\Delta T, T_{\min}\}$ , where  $T_{\min}$   
25           is a predetermined minimum size for the  
26           dynamic buffer threshold;  
27       reset the timer, upon expiration of the  
28           predetermined interval  $\Delta s$ ; and  
29       iterate the iteration counter, upon expiration of  
30           the predetermined time interval  $\Delta s$ .

1       27. The article of manufacture of claim 26 wherein the  
2       instructions are configured to be readable from the at  
3       least one carrier by at least one processor and thereby  
4       cause the at least one processor to operate so as to:

5           filter the sum of the sampled current queue size  
6                $Q(n)$  according to the relation:  
7                $\hat{Q}(n) = (1-\phi)\hat{Q}(n-1) + \phi Q(n)$ , wherein  $\phi$  is a  
8           predetermined parameter.

1       28. A signal embodied in a carrier wave and representing  
2       sequences of instructions which, when executed by at  
3       least one processor, cause the at least one processor to  
4       control the transmission of data packets through a  
5       network by controlling a Transmission Control Protocol  
6       (TCP) rate in a network device having a shared buffer  
7       with shared buffer space, by performing the steps of:  
8           organizing a forward data buffer into one or more  
9               queues that store at least one forward data  
10          packet;  
11          calculating a network device's advertised window  
12               size by implementing an integral control  
13          algorithm that uses information pertaining to

14           the one or more queues;  
15       providing the network device's advertised window  
16           size to a TCP source; and  
17       calculating a dynamic buffer threshold based, at  
18           least in part, upon the sum of queue sizes and  
19           the shared buffer space.

1       29. The signal of claim 28 wherein the step of  
2       organizing a forward data buffer further comprises:  
3           organizing the forward data buffer into one or more  
4           queues with one queue per service class.

1       30. The signal of claim 28 wherein the at least one  
2       forward data packet is stored according to its service  
3       class.

1       31. The signal of claim 28 wherein the step of  
2       calculating a network device's advertised window size  
3       further comprises:  
4           initializing a timer to a predetermined time  
5           interval  $\Delta t$ , and an iteration counter to a  
6           predetermined initial value  $n$ ;  
7           sampling a current queue size  $q_i(n)$  during the  
8           predetermined time interval  $\Delta t$ ;  
9           calculating a current error signal  $e_i(n)$  based, at  
10          least in part, upon the current queue size  
11           $q_i(n)$ ;  
12          calculating the network device's advertised window  
13          size  $W_i(n)$ , based, at least in part, upon the  
14          current error signal  $e_i(n)$  according to the



15 equation:  $W_i(n) = [W_i(n-1) + \alpha e_i(n)]_{W_{\min}}^{W_{\max}}$ , where  $\alpha$ ,  $W_{\max}$ ,  
16 and  $W_{\min}$ , are predetermined parameters;  
17 resetting the timer, upon expiration of the  
18 predetermined interval  $\Delta t$ ; and  
19 iterating the iteration counter, upon expiration of  
20 the predetermined time interval  $\Delta t$ .

1 32. The signal of claim 31 wherein the steps of  
2 calculating a filtered current error signal  $e_i(n)$  and  
3 calculating the network device's advertised window size  
4 further comprise:

5 filtering the current error signal  $e_i(n)$  according to  
6 the relation:  $\hat{e}_i(n) = (1 - \beta)\hat{e}_i(n-1) + \beta e_i(n)$ , where  $\beta$   
7 is a predetermined parameter; and  
8 calculating the network device's advertised window  
9 size  $W_i(n)$ , based, at least in part, upon the  
10 filtered current error signal  $\hat{e}_i(n)$  according to  
11 the equation:  $W_i(n) = [W_i(n-1) + \alpha \hat{e}_i(n)]_{W_{\min}}^{W_{\max}}$ , where  $\alpha$ ,  
12  $W_{\max}$ , and  $W_{\min}$ , are predetermined parameters.

1 33. The signal of claim 28 wherein the step of providing  
2 the network device's advertised window size to a TCP  
3 source further comprises:

4 carrying information relating to the network  
5 device's advertised window size by returning  
6 TCP acknowledgements in a receiver's advertised  
7 window field.

1 34. The signal of claim 28 wherein the step of providing  
2 the network device's advertised window size to a TCP

3 source further comprises:

4 updating a TCP receiver's advertised window size.

1 35. The signal of claim 34 wherein the step of updating  
2 a TCP receiver's advertised window size further  
3 comprises:

4 identifying whether a packet is an ACK packet, and,  
5 if not, putting the non-ACK packet in a reverse  
6 data buffer;

7 determining a service class for the identified ACK  
8 packet;

9 reading a TCP receiver's advertised window size

10 ( $RW_{rec}$ ) and a checksum ( $RCHKSUM$ ) from the  
11 identified ACK packet;

12 determining whether the TCP receiver's advertised  
13 window size  $RW_{REC}$ , is less than or equal to the  
14 calculated network device's advertised window  
15 size  $W_i(n)$  and, if not setting an advertised  
16 window field in the identified ACK packet equal  
17 to the calculated network device's advertised  
18 window size  $W_i(n)$  and updating the checksum  
19 field for the identified ACK packet.

1 36. The signal of claim 28 wherein the step of  
2 calculating a dynamic buffer threshold further comprises:

3 initializing a timer to a predetermined time  
4 interval  $\Delta s$  and an iteration counter to a  
5 predetermined initial value  $n$ ;

6 setting an initial dynamic buffer threshold  $T(0)$   
7 equal to a gain constant  $\gamma$  multiplied by a  
8 buffer size  $B$  and divided by a number of

9 service classes  $K$ ;  
10 sampling a current queue size  $q_i(n)$  during the  
11 predetermined time interval  $\Delta s$ ;  
12 calculating a sum of the sampled current queue size  
13 according to the equation:  $Q(n) = \sum_{i=1}^K q_i(n)$ ;  
14 determining whether the sum of the sampled current  
15 queue size is less than the product of the gain  
16 constant and the buffer size  $\gamma B$ ;  
17 if so, updating the dynamic buffer threshold  
18 according to  $\min\{T(n-1) + \Delta T, \gamma B\}$ , where  $\Delta T$  is  
19 a step size that controls the rate at  
20 which the dynamic buffer threshold  
21 changes;  
22 if not, updating the dynamic buffer threshold  
23 according to  $\max\{T(n-1) - \Delta T, T_{\min}\}$ , where  $T_{\min}$   
24 is a predetermined minimum size for the  
25 dynamic buffer threshold;  
26 resetting the timer, upon expiration of the  
27 predetermined interval  $\Delta s$ ; and  
28 iterating the iteration counter, upon expiration of  
29 the predetermined time interval  $\Delta s$ .

1 37. The signal of claim 36 wherein the step of  
2 calculating a sum of the sampled current queue size  
3 further comprises:  
4 filtering the sum of the sampled current queue size  
5  $Q(n)$  according to the relation:  
6  $\hat{Q}(n) = (1 - \phi)\hat{Q}(n-1) + \phi Q(n)$ , wherein  $\phi$  is a  
7 predetermined parameter.

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